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DESCRIPTION

BASE FABRIC FOR NON-COATED AIR BAGS, AND FIBERS FOR AIR BAGS

TECHNICAL FIELD

The present invention relates to a base fabric for non-coated air bags, and to fibers for air bags. More precisely, the invention relates to a base fabric for high-pressure inflatable, non-coated air bags, which has high tenacity and low air permeability necessary to air bags and which can be compactly folded and housed, and relates to fibers to give the base fabric for such air bags.

BACKGROUND ART

At present, air bags are indispensable for ensuring the safety of drivers and passengers in automobiles, and the percentage of air bag installation in automobiles is increasing.

Various matters are required for air bags, which are, for example, low air permeability for ensuring smooth inflation in collision, high tenacity for preventing the bags themselves from being damaged and broken, and flexibility for protecting drivers and passengers from being scratched on their faces by inflated air bags. The other important matters for air bags are that the base fabric for them is compactly foldable so as to be housed in a limited small space, and is inexpensive.

Base fabrics for air bags are grouped into two types, coated base fabrics and non-coated base fabrics. For the former, woven fabrics are coated with resin; and for the latter, woven fabrics are directly used as they are. In general, coated base fabrics are said to be advantageous for ensuring the above-mentioned low air permeability for air bags.

Many techniques have heretofore been disclosed for realizing air bags that are compactly foldable to save the necessary housing space, not interfering with high tenacity and low air permeability favorable to air bags. For example, Japanese Patent Laid-Open No. 41438/1989 says that a base fabric for air bags, which is composed of fiber filaments having a tenacity of at least 8.5 g/d and a monofilament fineness of at most 3 deniers, attains the above-mentioned object. Though silent on the type of the base fabric, coated or non-coated one, it substantially relates to a base fabric coated with an elastomer such as chloroprene rubber. In case where the technique disclosed is applied to non-coated base fabrics, they could have high tenacity and could be compactly foldable to save the necessary housing space, but their air permeability could not be lowered satisfactorily.

On the other hand, Japanese Patent Laid-Open No. 201650/1992 discloses a technique for producing a base fabric for air bags having high tenacity and capable of being compactly folded to save the housing space for it, for which are used

polyamide multifilaments composed of a plurality of modified cross-section monofilaments each having a fineness of from 1.0 to 12 deniers and having a degree of cross-section modification of from 1.5 to 7.0. However, the technique disclosed is to satisfy only the requirements for coated base fabrics for air bags, but is still problematic in point of the air permeation through non-coated base fabrics, especially the air permeation therethrough at the seams.

A technique relating to non-coated base fabrics is described in Japanese Patent Laid-Open No. 252740/1995, which says that a base fabric for non-coated air bags having low air permeability and capable of being compactly folded and housed in a limited small space is formed of flattened cross-section yarns having a degree of cross-section flatness of at least 1.5. However, the air permeation through the base fabric produced according to the technique disclosed is not lower than 0.3 $cc/cm^2/sec$ under low pressure (124 Pa), and does not satisfy lower air permeation recently required in the art.

On the other hand, dual-system inflators are being investigated for satisfying the US Act VMVSS208 revised in 2000. These are to inflate air bags in two stages, through which the gas pressure in the second stage inflation is larger than that through conventional inflators. For these, therefore, the base fabric for air bags is required to have lower air permeability under high pressure than before, and is required not to cause

yarn distortion and slippage from sewing threads at the seams (this is hereinafter referred to as seam distortion).

From this viewpoint, for example, Japanese Patent 2,950,954 discloses a non-coated base fabric made of yarns having a total fineness of from 300 to 400 dtex, but this could not still solve the problem of seam distortion in the base fabric. Japanese Patent Laid-Open No. 2359/1996 discloses a base fabric for air bags, of which the warp/weft cover factor falls between 900 and 1400. In this, the residual oil content of the base fabric and the slip resistance thereof are specifically defined. However, this could not still solve the problem of seam distortion in the base fabric.

The present invention has been achieved as a result of investigations to solve the problems in the prior art mentioned above.

Specifically, the object of the invention is to provide a base fabric for non-coated air bags which satisfies all the requirements of high tenacity, low air permeability and compact foldability indispensable to air bags and which further satisfies the advanced requirements of low air permeability under high pressure especially at the seams, not causing seam distortion, so as to be suitable to air bags for high-pressure inflation, and also to provide fibers for air bags.

DISCLOSURE OF THE INVENTION

The base fabric for non-coated air bags of the invention has the following essential constitution.

In the base fabric for non-coated air bags of the invention, both the warp and the weft or either of them comprise synthetic fiber multifilaments of flattened cross-section monofilaments having a degree of flatness of from 1.5 to 8.0 and having a monofilament fineness of at moat 10 dtex and a total fineness of from 200 to 1000 dtex, and the base fabric satisfies all the following (1) to (3):

(1) its cover factor falls between 1700 and 2200;

(2) its air permeability under atmospheric pressure is at most 0.1 $cc/cm^2/sec$; and

(3) its air permeability under high pressure is at most 20 $cc/cm^2/sec$.

Preferred embodiments of the base fabric for non-coated air bags of the invention are the following (a) to (e). Satisfying these conditions, the base fabric is expected to get better results.

(a) After inflated, the air permeation through the base fabric under high pressure is at most 50 $cc/cm^2/sec$.

(b) The horizontal index, HI, of the synthetic fiber multifilaments is at least 0.75 in terms of the cosine of the angle at which the horizontal direction of the base fabric crosses the direction of the major axis of the cross section of each monofilament.

(c) The number of residual entanglements in the warp drawn out of the base fabric is at most 10/m.

(d) The residual oil content of the base fabric is at most 0.1 % by weight.

(e) The synthetic fiber multifilaments are of a polyamide having a viscosity relative to sulfuric acid of at least 3.0.

The fibers for air bags of the invention have the following essential constitution.

The fibers for air bags comprise synthetic fiber multifilaments and satisfy all the following (4) to (7):

(4) the degree of flatness of each monofilament, which is indicated by the ratio of the length, a, of the largest major axis to the length, b, of the largest minor axis, a/b, of the cross section of the monofilament, falls between 1.5 and 8.0;

(5) the degree of surface smoothness of each monofilament in the direction of the major axis of the cross section, which is indicated by the ratio of the length, c, of the smallest minor axis to the length, b, of the largest minor axis, c/b, is at least 0.8;

(6) the monofilament fineness is at most 10 dtex; and

(7) the length, b, of the largest minor axis is at most 15 μm.

Satisfying the following conditions (f) and (g), the fibers for air bags of the invention are expected to get better results.

(f) After stretched under tension, the number of residual

entanglements in the fibers is at most 15/m.

(g) The synthetic fiber multifilaments are of a polyamide having a viscosity relative to sulfuric acid of at least 3.0.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graphic view showing the monofilament cross-section profile of the synthetic fiber multifilaments that constitute the base fabric for non-coated air bags of the invention.

Fig. 2 is a schematic view showing a method for producing the polyamide fibers for air bags of the invention.

Fig. 3 is a graphic view showing the cross-section profile of the orifice of the spinneret used herein for producing flattened cross-section fibers.

BEST MODES OF CARRYING OUT THE INVENTION

The invention is described in detail hereinunder.

The total fineness of the synthetic fiber multifilaments that constitute the base fabric for non-coated air bags of the invention indispensably falls between 200 and 1000 dtex, preferably between 200 and 700 dtex. The base fabric that comprises synthetic fiber multifilaments having a total fineness of smaller than 200 dtex could be compactly folded to save the housing space for it, but it is unfavorable since its tenacity is low and the air bags made of it will burst while they inflate

or when the inflated air bags collide against drivers or passengers. On the other hand, synthetic fiber multifilaments having a total fineness of larger than 1000 dtex satisfy the tenacity and the safety necessary for air bags, but could not satisfy another requirement of compact foldability necessary to the invention.

Air bags are designed in different ways, depending on the type of the automobiles and the site thereof in which they are installed, and the total fineness of the synthetic fiber multifilaments that constitute the base fabric for such air bags shall be suitably determined. For example, in ordinary sedans, it is desirable that the synthetic fiber multifilaments for air bags to be installed at the driver seat and the passenger seat have a total fineness of from 300 to 500 dtex. The total fineness of the multifilaments falling within the range satisfies both the necessary tenacity of air bags that must withstand the high inflator gas pressure to rapidly restrain drivers and passengers from being damaged in collision and the compact foldability thereof that must be housed in a relatively small space in the steering wheel at a driver seat or in the dashboard at a passenger seat.

On the other hand, side air bags to be installed at both sides of a driver seat and a passenger seat are required to have high tenacity in order that they withstand an inflator gas pressure which is generally planned high so as to rapidly restrain

drivers and passengers from being damaged in flank collision. For these, therefore, it is desirable that the total fineness of the synthetic fiber multifilaments to constitute the base fabric falls between 450 and 700 dtex.

Inflatable curtains are also required to be folded and housed in a limited small space. For the base fabric for these, therefore, the total fineness of the multifilaments preferably falls between 200 and 500 dtex.

The monofilament fineness of the synthetic fiber multifilaments that constitute the base fabric for non-coated air bags of the invention is indispensably at most 10 dtex, preferably at most 7 dtex, more preferably at most 5 dtex. In general, base fabrics of fibers having a smaller monofilament fineness are more flexible, and they can be more compactly folded and housed in a smaller space. With the reduction in the monofilament fineness of the multifilaments that constitute the base fabric, the cover factor of the base fabric increases, and, as a result, the air permeation through the base fabric is lowered. Multifilaments having a monofilament fineness of larger than 10 dtex are unfavorable, since the base fabric comprising them could not be compactly folded and housed in a small space and its air permeability is high, and, after all, the base fabric is unsuitable to air bags.

Regarding the monofilament cross-section profile of the multifilaments, the degree of flatness of the monofilament, which

is indicated by the ratio of the length, a, of the largest major axis to the length, b, of the largest minor axis, a/b, of the cross section of the monofilament, indispensably falls between 1.5 and 8.0, preferably between 2.0 and 6.0. In case where the synthetic fiber multifilaments having the flattened cross-section profile as in the defined range are woven into a base fabric, they are so aligned that the major axis of the cross section of each monofilament runs in the horizontal direction of the resulting base fabric owing to the general tension applied to all the fibers while they are woven. As a result, the void space per the unit area of the base fabric is reduced, and the air permeability of the base fabric is thereby reduced as compared with that of a base fabric of round cross-section fibers having a fineness of the same level. In case where the air permeation of the same level as that through a base fabric of round cross-section fibers is taken into consideration for the base fabric of the flattened cross-section fibers, the necessary amount of the flattened cross-section fibers for the base fabric is lowered. In other words, the flattened cross-section fibers as in the defined range can form a base fabric for air bags that satisfies both low air permeability and compact foldability to save the housing space for it. If, however, the degree of flatness of the flattened cross-section fibers is smaller than 1.5, the difference between the fibers and ordinary round cross-section fibers is small, and the

flattened cross-section fibers could not satisfactorily exhibit their effect. On the other hand, if the degree of flatness of the flattened cross-section fibers is larger than 8.0, the effect of the fibers is saturated and is no more augmented. If so, in addition, high-tenacity fibers of high quality necessary for air bags, concretely those having a tenacity of at least 6.5 cN/dtex are difficult to obtain, and, moreover, the flat fibers having such a large degree of flatness could not be smoothly woven into fabrics, or that is, their workability into woven fabrics is extremely poor. For these reasons, such too much flattened fibers are unfavorable.

As so mentioned in the above, the synthetic fiber multifilaments that constitute the base fabric for non-coated air bags of the invention are characterized in that the monofilaments all have a flattened cross-section profile and are so aligned that the major axis of the cross section of each monofilament runs in the horizontal direction of the base fabric.

To quantitatively express it, a horizontal index (HI) is defined herein for the alignment of the monofilaments. The horizontal index, HI is indicated by the mean value of the cosine (hi) of the angle (θ) at which the major axis of the flattened cross section of each monofilament of the base fabric crosses the horizontal direction of the base fabric. Numerically, HI is represented by the following equation:

$$HI = (\Sigma hi)/f$$

wherein hi = $\cos\theta$,

θ is the angle at which the major axis of the flattened cross section of each monofilament crosses the horizontal direction of the base fabric, and

f is the number of monofilaments measured.

Preferably, the horizontal index HI of the base fabric that comprises the flattened cross-section fibers of the invention is at least 0.75, more preferably at least 0.85, even more preferably at least 0.90. With the horizontal index HI defined to fall within the range, the base fabric ensures the intended good foldability to save the housing space for it and the intended low air permeability as in the above, and therefore attains the object of the invention.

The cover factor of the base fabric for non-coated air bags of the invention indispensably falls between 1700 and 2200, preferably between 1800 and 2100.

The cover factor is represented by:

$(D1 \times 0.9)^{1/2} \times N1 + (D2 \times 0.9)^{1/2} \times N2$,

in which D1 (dtex) indicates the total fineness of the warp;

N1 (/2.54 cm) indicates the texture density of the warp;

D2 (dtex) indicates the total fineness of the weft; and

N2 (/2.54 cm) indicates the texture density of the weft.

If its cover factor is smaller than 1700, the mechanical properties of the base fabric are poor, and, in particular, the

air permeation (P_H) thereof under high pressure is high. If so, in addition, the multifilaments constituting the base fabric are often distorted at the seams. As a result, the base fabric is unfavorable for non-coated air bags, since the air bags made of it could not well serve as safety guards. On the contrary, if the cover factor of the base fabric is larger than 2200, or that is, if the texture density thereof is too high, it is unfavorable since the base fabric could not be compactly folded to save the housing space for it. If so, in addition, the necessary amount of the fibers for the base fabric increases, and the base fabric is after all expensive.

Accordingly, the cover factor of the base fabric is significantly related to the compact foldability thereof, and it is important that the cover factor of the base fabric for non-coated air bags of the invention falls within the suitable range as so defined in the above.

For the base fabric for non-coated air bags, it is necessary that the air permeation through it under low pressure, P_L, is at most 0.1 cc/cm^2/sec, preferably at most 0.08 cc/cm^2/sec. It is also necessary that the air permeation through the base fabric under high pressure, P_H, is at most 20 cc/cm^2/sec, preferably at most 15 cc/cm^2/sec.

P_L indicates a degree of air permeation measured according to the method defined in JIS L1096 (6.27.1 Method A). P_H indicates a degree of air permeation measured as follows: Air having a

controlled pressure of 19.6 KPa is made to run through a circular test piece having a diameter of 10 cm, and the amount of the air having passed through the test piece is measured by the use of a laminar flow air permeation meter.

P_L and P_H indicate the necessary characteristics of the base fabric for air bags, or that is, they directly indicate the inflatablity of air bags. Having P_L and P_H each falling within the defined range, air bags well serve as safety guards and attain the object of the invention. If P_L and P_H are higher than 0.1 cc/cm^2/sec and 20 cc/cm^2/sec, respectively, the air bags could not smoothly inflate in collision and are therefore unfavorable since they are useless for safety guards.

After stretched, the degree of air permeation through the base fabric under high pressure, P_S, is preferably at most 50 cc/cm^2/sec. With P_S falling within the range, the air bags made of the base fabric ensure safe protection of drivers and passengers since the inflated air bags well keep their inner pressure when drivers or passengers have pushed in them.

P_S is measured as follows: A sample of the base fabric having a length of 20 cm and a width of 15 cm is stretched under tension of 1764 N at a pulling rate of 200 mm/min in the longitudinal direction. Air having a controlled pressure of 19.6 KPa is made to run through a circular part having a diameter of 10 cm in the center of the sample, and the amount of the air having passed through the circular part is measured by the use

of a laminar flow air permeation meter.

Also preferably, the number of residual entanglements in the warp of the base fabric is at most 10/m. With residual entanglements falling within the range, the base fabric can be prevented from being distorted at the seams. The number of residual entanglements in the warp is significantly related to the above-mentioned horizontal index HI. Concretely, when the number of residual entanglements in the warp is not larger than 10/m, HI of the base fabric tends to increase and the air permeation through the base fabric is kept low.

Also preferably, the residual oil content of the warp and the weft of the base fabric is at most 0.1 % by weight. With the residual oil content falling within the range, the frictional force of the monofilaments that constitute the base fabric increases and the air permeation through the base fabric especially at the seams is lowered.

Next described are the fibers for air bags of the invention.

The monofilament cross-section profile of the fibers for air bags of the invention is flattened as in Fig. 1, differing from an ordinary oval or diamond shape. The degree of flatness of the monofilament cross section falls between 1.5 and 8.0, indicated by the ratio of a/b in which a is the length of the largest major axis and b is the length of the largest minor axis of the cross section. The cross-section profile is formed by aligning plural circles in a line, for which the diameter of

each circle corresponds to the minor axis of the cross section.

Regarding the monofilament cross-section profile, the degree of surface smoothness of each monofilament in the direction of the major axis of the cross section, which is indicated by the ratio of the length, c, of the smallest minor axis to the length, b, of the largest minor axis, c/b, is indispensably at least 0.8, preferably at least 0.85. With the degree of surface smoothness falling within the range, the frictional force of the monofilaments increases and the air permeation through the base fabric for air bags made of the fibers is well lowered. If fibers having a degree of surface smoothness of smaller than 0.8 are formed into a base fabric for air bags, the air permeation through the base fabric, especially at the seams could not be lowered, and therefore the fibers are not suitable for air bags intended in the invention.

Indispensably in the invention, the length, b, of the largest minor axis is at most 15 μm, and the monofilament fineness is at most 10 dtex. With the length, b, of the largest minor axis and the monofilament fineness falling within the range, the fibers are favorable to the base fabric for non-coated air bags intended in the invention.

The constitutive components of the fibers for air bags of the invention are not specifically defined. For ensuring high tenacity and good flexibility favorable to air bags, polyamide having a viscosity relative to sulfuric acid of at

least 3.0 is preferred for the fibers. The polyamide may be either a homopolymer or a copolymer, and it may contain inorganic substances such as titanium oxide, silicon oxide and calcium carbonate, and also other chemicals such as weather-proofing agent and antioxidant, for improving the color, the weather resistance and the oxidation resistance of the polymer fibers.

Next described is a method for producing the fibers for air bags of the invention.

The fibers for air bags of the invention can be produced in any ordinary melt-spinning method. Fig. 2 shows one example of the method for producing polyamide fibers for air bags.

As illustrated, the yarn (Y) having been spun out through the spinning pack (0) in a melt-spinning machine is led to pass through the heating zone (1) disposed just below the spinneret. Preferably, the length of the heating zone (1) falls between 100 and 200 mm. Having passed through the heating zone of which the length is defined to fall within the range, the fibers can readily have the desired tenacity and the desired degree of flatness favorable to air bags intended in the invention. Next, the yarn (Y) is cooled and solidified by the chill air that is blowing at a speed of 20 to 50 m/min in the chilling zone (2). Then, after having passed through the spinning duct (3), the yarn receives oil from the oil supply unit (4), and then taken up by the spun yarn-taking up rollers (5) and (6).

Next, the yarn (Y) is led to run along the hot rollers

(7), (8) and (9) each running at a high speed, in that order and is thus drawn by these rollers. For further increasing their tenacity, the fibers are preferably drawn in two or more stages. Next, the yarn is wound around the rollers (10) and relaxed therearound, and then led to the control guides (12, 12') and the entangling unit (11) in which it is entangled. With that, the yarn is wound up in the winder (13). The relaxation is important for determining the shrink property of the fibers obtained. In general, the fibers are relaxed to a degree of from 3 to 15 % in order that they have a desired degree of shrinkage favorable to air bags. After stretched, the fibers are entangled to have at most 15 entanglements/m, for which pressure air of from 0.05 to 0.4 MPa is preferably applied to the fibers in the entangling unit.

Fig. 3(A) shows the cross-section profile of the orifice of the spinneret usable for obtaining the flattened cross-section fibers of the invention. Regarding the structure of the spinneret orifice, the round parts (d) at both ends and in the inside between them are connected in a line via the slit parts (e). For efficiently obtaining the flattened cross-section fibers of the invention that satisfy the monofilament fineness, the degree of flatness, the degree of surface smoothness in the direction of the major axis of the cross section and the length of the major axis of the cross section defined herein, it is desirable that the number of the round parts (d) is at least

2, the diameter of each round part falls between 0.15 and 0.25 mm, the width of the slit (e) falls between 0.10 and 0.20 mm, and the length of the slit falls between 0.10 and 0.20 mm. The orifice profile of Fig. 3(B) is undesirable, since the surface smoothness in the direction of the major axis of the cross section of the fibers produced through it could not satisfy the requirement defined herein and the air permeation through the base fabric for air bags made of the fibers could not be low.

For producing the base fabric for non-coated air bags of the invention, or that is, for weaving the base fabric from the fibers of the invention, usable are a water-jet loom, a rapier loom, an air-jet loom, etc. The residual oil content of the base fabric for non-coated air bags of the invention is preferably at most 0.1 % by weight. For weaving the base fabric from the fibers, therefore, preferably used is a water-jet loom as facilitating the oil removal from the fibers. Also preferably, the tension of the warp falls between 0.2 and 0.6 cN/dtex in the process of weaving the fabric. Under the tension falling within the range, the flattened cross-section fibers are well woven into the intended base fabric and are favorably aligned in the woven fabric, or that is, the horizontal index HI of the fibers constituting the woven fabric well meets the requirement defined herein and the air permeability of the woven fabric can be lowered. After having been thus woven, the base fabric is preferably scoured and/or thermally set at 160 to 190°C.

The embodiments of the invention have been described in detail hereinabove. The base fabric made of the flattened cross-section fibers of the invention is characterized in that it is favorable to air bags, especially to non-coated air bags. Specifically, the base fabric favorable to such air bags of the invention is characterized in that its air permeability is low, especially at the seams, and it is compactly foldable to save the housing space for it. These characteristics of the base fabric of the invention result from the flattened cross-section fibers that constitute the base fabric. The significant features characteristic of the fibers are described below.

As mentioned hereinabove, (1) in the base fabric of flattened cross-section fibers of the invention, the monofilaments of the fibers are so aligned that the major axis of the cross section of each monofilament runs in the horizontal direction of the woven fabric. Therefore, the cover factor of the base fabric is high and the air permeability thereof is low. In addition, the base fabric is compactly foldable to save the housing space for it, and it is thin and flexible. Moreover, (2) the cross section of each monofilament of the flattened cross-section fibers of the invention is a rectangular cross section. Specifically, it is a flattened cross section that is formed by aligning plural circles in a line, for which the diameter of each circle corresponds to the minor axis of the cross section. The length of the minor axis is at most 15 μm.

For example, when the length of the minor axis is 10 μm, falling within the preferred range thereof, the fineness of the monofilament corresponds to 1 denier (1.1 dtex) and falls in the category of microfibers. In the base fabric of the invention, the flattened cross-section fibers that are considered to fall in the category of microfibers are aligned in the horizontal direction of the base fabric, and, as a result, the base fabric of the invention can be compactly folded to save the housing space for it, and it is thin and flexible. Accordingly, the base fabric of the invention is comparable to ordinary base fabrics of microfibers in point of the texture. Base fabrics of microfibers are known for air bags, but it is difficult to stably spin microfibers in a direct spinning process. On the other hand, microfibers produced in a process of sea/island polymer alignment are expensive and could not be put into practical use.

For air bags, the base fabric of the invention is superior to any other conventional base fabrics made of ordinary fibers of thinned monofilaments, since its air permeability is low, it is compactly foldable to save the housing space for it, and it is thin and flexible. Moreover, the base fabric of the invention can be readily produced in any ordinary melt-spinning process or direct spinning and drawing process, and its practicability is significant.

EXAMPLES

The invention is described more concretely with reference to the following Examples and Comparative Examples. The physical properties referred to in the specification and in the following Examples are measured according to the methods mentioned below.

[Fineness]

Measured according to JIS L-1013.

[Tenacity, Elongation]

Measured according to JIS L-1013. The length of the sample tested is 25 cm, and the pulling rate is 30 cm/min.

[Viscosity relative to sulfuric acid]

2.5 g of a sample to be tested is dissolved in 25 cc of 96 % sulfuric acid, and its viscosity is measured at a constant temperature of 25°C in a thermostat, using an Ostwald viscometer.

[Degree of flatness]

On the optical microscopic picture (× 200) of a sample to be tested, the cross section of each monofilament is analyzed. The length, a, of the largest major axis in the direction of the major axis of the cross section; and the length, b, of the largest minor axis in the direction of the minor axis of the cross section are measured. The data of ten monofilaments thus measured are averaged, from which the degree of flatness is obtained according to the following equation:

Degree of Flatness = a/b

[Horizontal index, HI]

On the optical microscopic picture (× 200) of a sample to be tested, like that taken for the measurement of the degree of flatness as above, the angle θ at which the major axis of the cross section of each flattened cross-section fiber crosses the horizontal direction of the base fabric is measured. Based on the mean value of the cosine of the angle thus measured, the horizontal index, HI, is obtained according to the following equation. The number of the monofilaments measured, f = 100.

$$HI = (\Sigma hi)/f$$

wherein $hi = \cos\theta$,

θ is the angle at which the major axis of the flattened cross section of each monofilament crosses the horizontal direction of the base fabric, and

f is the number of the monofilaments measured.

[Surface smoothness]

On the optical microscopic picture (× 200) of a sample to be tested, the cross section of each monofilament is analyzed. The length, b, of the largest minor axis and the length, c, of the smallest minor axis in the direction of the minor axis of the cross section are measured. The data of ten monofilaments thus measured are averaged, from which the degree of surface smoothness is obtained according to the following equation:

$$\text{Degree of Surface Smoothness} = c/b$$

[Number of residual entanglements, and the number of

entanglements after stretching treatment]

For measuring the number of the residual entanglements in a base fabric, each one of the warp is nipped and drawn out of the base fabric, at an angle of from 20 to 45° relative to the direction of the warp and at a pulling rate of from 40 to 60 sec/m or so. The number of the entanglements/meter in the thus-drawn warp is measured in a method of dipping the sample in a water bath. 10 samples are measured, and the data are averaged to obtain the number of the entanglement/m of the warp. The water bath has a length of 70 cm, a width of 15 cm and a depth of 5 cm. This is partitioned at 10 cm from each end in the longitudinal direction, and filled with pure water to a depth of about 3 cm. To remove the influence of impurities such as oil on the measurement, the pure water in the bath is exchanged for fresh one in every measurement.

For measuring the number of entanglements after stretched, the fiber sample having a length of 1.0 m is stretched by applying a load of 2 cN/dtex thereto for 5 seconds, and after the load has been removed, the sample is measured in a water bath according to the same method as above.

[Residual oil content]

The warp and the weft are individually drawn out of a base fabric in the same manner as that for the measurement of the residual entanglements as above, and the samples are measured according to JIS L-1096 (6.36.1 Method A) (alcohol/benzene

extraction method). The details are as follows: About 5 g of a sample piece is prepared, and its weight is accurately measured. This is lightly pushed into a Soxhlet extractor, not using a cylindrical paper filter therein, and 120 ml of a mixture of alcohol/benzene (1/2 by volume) is put into the accessory flask attached to the extractor. With that, the flask is heated for 3 hours in a water bath, and the solution formed in the sample section in the extractor is returned to the flask. The contents of the flask are concentrated to about 3 ml, and moved to a balance bottle. The bottle is put in a water bath, and the solvent is evaporated away. The absolute dry weight of the residue is measured. The same test is repeated two times.

The residue obtained according to the method of JIS L-1096 (3.36.1 Method A) is collected, and the monomer/oligomer content (% by weight) of the polyamide in the residue is measured through gas chromatography and high-performance liquid chromatography. For the quantification standards, used are adipic acid and hexamethylenadipamide (special-grade chemicals from Tokyo Chemical) and nylon 66 cyclic trimer (produced by Toray).

The data obtained in the two tests are averaged, and the oil content of the sample is obtained according to the following equation.

Oil Content

= (data in alcohol/benzene extraction) - (data in monomer/oligomer analysis).

[Tensile strength of base fabric]

Measured according to JIS L-1096 (6.12.1 Method A).

[Tear strength of base fabric]

Measured according to JIS L-1096 (6.15.2 Method A-2).

[Cover factor]

Represented by:

$(D1 \times 0.9)^{1/2} \times N1 + (D2 \times 0.9)^{1/2} \times N2$,

in which D1 (dtex) indicates the total fineness of the warp;

N1 (/2.54 cm) indicates the texture density of the warp;

D2 (dtex) indicates the total fineness of the weft; and

N2 (/2.54 cm) indicates the texture density of the weft.

[Air permeability under low pressure, P_L]

Measured according to JIS L-1096 (6.27.1 Method A).

Its details are as follows: A base fabric to be tested is cut to prepare its sample having a length of 20 cm and a width of 15 cm. Air having a controlled pressure of 124 Pa is made to run through a circular part having a diameter of 10 cm of the sample, and the amount of the air ($cc/cm^2/sec$) having passed through the circular part is measured by the use of a laminar flow air permeation meter.

[Air permeability under high pressure, P_H]

A base fabric to be tested is cut to prepare its sample having a length of 20 cm and a width of 15 cm. Air having a controlled pressure of 19.6 KPa is made to run through a circular

part having a diameter of 10 cm of the sample, and the amount of the air ($cc/cm^2/sec$) having passed through the circular part is measured by the use of a laminar flow air permeation meter.

[Air permeability after stretched, P_S]

A base fabric to be tested is cut to prepare its sample having a length of 20 cm and a width of 15 cm. The sample is stretched under tension of 1764 N at a pulling rate of 200 mm/min in the longitudinal direction. Air having a controlled pressure of 19.6 KPa is made to run through a circular part having a diameter of 10 cm of the sample, and the amount of the air ($cc/cm^2/sec$) having passed through the circular part is measured by the use of a laminar flow air permeation meter.

[Air permeability at seams]

Using a sewing machine, Juki Corporation's MH-380 Model, two sheets of a base fabric to be tested, each having a length of 20 cm and a width of 20 cm, are sewed with sewing thread of 1400 dtex in a mode of multi-thread chain stitch, with leaving a margin of 2 cm to sew up them. The needle used is TV×7 #19; the sewing pitch is 3 mm; and the distance between the two stitch lines is 2 mm. Air having a controlled pressure of 19.6 KPa is made to run through a circular part having a diameter of 10 cm in the center of the sample with the seams, and the amount of the air ($cc/cm^2/sec$) having passed through the circular part is measured by the use of a laminar flow air permeation meter.

[Seam distortion]

Two sheets of a base fabric to be tested are prepared, each having a length of 7 cm and a width of 7 cm. With one on top of the other so that the warp and the weft are individually in the same direction in the two, these are sewed in a mode of multi-thread chain stitch. The margin left to sew up them is 2.5 cm; the needle thread and the bobbin thread used are both of nylon 6.6 1400 dtex/one; the sewing machine used is Juki Corporation's MH-380 Model; and the needle used is TV×7 #19. The thus-sewed sample is set in a tensile tester, in which it is held by a chuck of 5 cm wide with a margin of 1 cm left at both ends. In that condition, an elastic stress of 1274 N is applied to the sample, and the length of the gap having appeared between the base fabric and the sewing thread is read with a measure. Large five gaps are thus measured, and the data are averaged.

[Thickness of base fabric]

A base fabric to be tested is sewed up to form an air bag having a volume of 60 liters. This is bellows-wise folded four times both in the opposite horizontal directions and then four times both in the opposite vertical directions. Having thus folded, this has an area of 150 × 150 cm. A load of 4000 g is applied to this, and the thickness of the thus-folded bag is measured.

[Examples 1 to 13]

Using an extruder-type spinning machine, nylon 66 chips having a viscosity, relative to 98 % sulfuric acid at 25°C, of 3.7 were melt-spun at 295°C.

Precisely, the nylon melt was spun out of a spinning pack with a spinneret having an orifice profile as in Table 1; then led to pass through a hot zone disposed just below the spinneret (the hot zone was heated at 230°C and had a length of 150 mm); then cooled and solidified in a chilling zone with chill air blowing at a speed of 30 m/min; then lubricated with an oiling roller; then wound around a take-up roll, a feed roll, a first stretch roll, a second stretch roll and a tension control roll in that order to thereby draw the fibers in two stages to a total draw ratio of 4.1 times; then relaxed by 7 %; and finally wound up in a winder at a speed of 3800 m/min. After relaxed, the fibers were entangled with pressure air of 0.3 MPa applied thereto in an entangling unit. The physical properties of the synthetic fiber multifilaments for air bags, thus produced according to the process as above, are shown in Table 1.

Table 1

		Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8
Spinneret Orifice Profile	rounded, diameter (mm)	0.20	0.20	0.15	0.20	0.15	0.20	0.20	0.20
	number of sections (-)	5	3	5	5	5	5	5	5
	slit, width (mm)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	length (mm)	0.10	0.10	0.20	0.10	0.10	0.10	0.10	0.10
467	Total fineness (dtex)	467	467	467	467	467	467	467	467
	Number of filaments (-)	96	96	96	72	144	96	96	96
	Monofilament fineness (dtex)	4.86	4.86	4.86	6.49	3.24	4.86	4.86	4.86
	Degree of flatness (-)	3.60	2.21	5.51	3.42	3.48	3.60	3.60	3.60
	Degree of surface smoothness (-)	0.97	0.97	0.93	0.96	0.97	0.97	0.97	0.97
	Length of largest minor axis (μm)	10	13	8	13	9	10	10	10
	Tenacity (cN/dtex)	7.92	7.86	7.68	7.95	7.72	7.92	7.92	7.92
	Elongation (%)	22.1	23.0	20.4	23.9	21.1	22.1	22.1	22.1
	Shrinkage in boiling water (%)	6.2	6.2	6.1	6.3	6.2	6.2	6.2	6.2
	Number of entangled after stretched (/m)	10	10	12	9	13	10	10	10

Table 1 - continued

		Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14
Spinneret Orifice Profile	rounded, diameter (mm)	0.20	0.20	0.20	0.20	0.20	0.20
	number of sections (-)	5	4	5	5	5	5
	slit, width (mm)	0.10	0.10	0.10	0.10	0.10	0.10
	length (mm)	0.10	0.20	0.10	0.10	0.10	0.10
Physical Properties of Fibers	Total fineness (dtex)	467	467	467	350	700	467
	Number of filaments (-)	96	96	96	72	144	96
	Monofilament fineness (dtex)	4.86	4.86	4.86	4.86	4.86	4.86
	Degree of flatness (-)	3.58	3.54	3.51	3.58	3.39	3.60
	Degree of surface smoothness (-)	0.96	0.92	0.96	0.94	0.95	0.97
	Length of largest minor axis (μm)	10	10	10	10	11	10
	Tenacity (cN/dtex)	7.67	7.88	7.68	7.96	8.08	7.92
	Elongation (%)	20.5	23.4	24.6	23.5	23.4	22.1
	Shrinkage in boiling water (%)	6.2	6.3	9.0	6.2	6.1	6.2
	Number of entangled after stretched (/m)	14	10	10	10	8	10

Next, the resulting synthetic fiber multifilaments were warped under tension of 0.3 cN/dtex at a speed of 200 m/min, and then woven into a fabric by the use of a water-jet loom (Tsudakoma's ZW303) driving at a revolution speed of 800 rpm. Next, the thus-woven fabric was scoured by dipping it in a hot water bath at 80°C that contained 0.5 g/liter of sodium alkylbenzenesulfonate and 0.5 g/liter of soda ash, for 3 minutes, followed by drying it in an atmosphere at 130°C for 3 minutes. Finally, this was thermally set at 180°C for one minute to obtain a base fabric for air bags.

The base fabric for non-coated air bags obtained according to the process as above was analyzed and tested for the texture density (count of warp/weft) and for the properties thereof. The data are in Table 2.

Table 2

		Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8
Properties of Base Fabric	Texture density (warp/weft) (/2.54 cm)	48/48	48/48	48/48	48/48	48/48	45/45	51/51	53/53
	Cover factor (-)	1967	1967	1967	1967	1967	1844	2090	2172
	Air Permeability (cc/cm^2/sec)								
	under low pressure (124 Pa)	0.02	0.04	0.02	0.05	0.02	0.08	0.01	0.01
	under high pressure (19.6 KPa)	11	15	8	14	9	19	6	6
	after stretched (19.6 KPa)	23	37	21	31	19	42	15	12
	at the seams (19.6 KPa)	21	26	19	28	19	29	11	9
	Seam distortion (mm)	1.2	1.5	1.1	1.3	1.1	1.7	1.1	0.9
	Thickness of base fabric (mm)	0.27	0.27	0.27	0.27	0.26	0.24	0.29	0.32
	Tensile strength (N/cm)	620	624	618	624	626	580	639	668
	Tear strength (N)	197	201	187	210	187	168	211	219
	Number of residual entanglements (/m)	4	3	4	4	5	3	4	4
	Horizontal index (-)	0.95	0.94	0.96	0.94	0.92	0.95	0.95	0.94
	Residual oil content of base fabric (%)	0.02	0.03	0.03	0.03	0.04	0.03	0.04	0.06

Table 2 - continued

		Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14 not scoured
Properties of Base Fabric	Texture density (warp/weft) (/2.54 cm)	48/48	48/48	48/48	48/48	48/48	45/45
	Cover factor (-)	1967	1967	1967	1967	1967	1844
	Air Permeability ($cc/cm^2/sec$)						
	under low pressure (124 Pa)	0.02	0.02	0.04	0.01	0.02	0.03
	under high pressure (19.6 KPa)	11	12	14	8	10	12
	after stretched (19.6 KPa)	34	25	17	18	26	29
	at the seams (19.6 KPa)	30	23	15	23	20	27
	Seam distortion (mm)	1.7	1.7	0.9	1.1	1.4	1.5
	Thickness of base fabric (mm)	0.27	0.27	0.27	0.24	0.36	0.27
	Tensile strength (N/cm)	613	620	611	533	772	621
	Tear strength (N)	217	200	187	168	288	211
	Number of residual entanglements (/m)	6	4	4	3	4	5
	Horizontal index (-)	0.93	0.95	0.95	0.95	0.94	0.94
	Residual oil content of base fabric (%)	0.08	0.03	0.04	0.05	0.05	0.10

[Example 14]

In the same manner as in Example 1, fibers for air bags were produced, and these were woven and thermally set to give a base fabric for non-coated air bags. In this, however, the woven fabric was not scoured. Table 1 shows the orifice profile of the spinneret used and the physical properties of the fibers produced; and Table 2 shows the properties of the base fabric produced.

[Comparative Examples 1 to 5]

Fibers for air bags were produced in the same manner as in Example 1, for which, however, the orifice profile of the spinneret used is as in Table 3. The physical properties of the synthetic fibers for air bags obtained are in Table 3.

Table 3

		Co. Ex. 1	Co. Ex. 2	Co. Ex. 3	Co. Ex. 4	Co. Ex. 5	Co. Ex. 6	Co. Ex. 7	Co. Ex. 8
Spinneret Orifice Profile	rounded, diameter (mm)	0.30	0.20	-	0.30	0.30	0.20	0.20	0.20
	number of sections (-)	1	5	-	3	2	5	5	5
	slit, width (mm)	-	0.10	0.20	0.10	0.10	0.10	0.10	0.10
	length (mm)	-	0.10	1.40	0.20	0.80	0.10	0.10	0.10
Physical Properties of Fibers	Total fineness (dtex)	467	467	467	467	467	467	467	467
	Number of filaments (-)	96	96	96	96	96	96	96	96
	Monofilament fineness (dtex)	4.86	4.86	4.86	4.86	4.86	4.86	4.86	4.86
	Degree of flatness (-)	1.00	3.61	3.33	3.41	3.46	3.61	3.56	3.60
	Degree of surface smoothness (-)	(circular cross section)	0.97	(oval cross section)	0.71	0.74	0.97	0.97	0.97
	Length of largest minor axis (μm)	(23)	10	(11)	10	10	10	10	10
	Tenacity (cN/dtex)	8.03	7.92	8.02	7.91	7.89	7.92	7081	7.92
	Elongation (%)	24.3	22.1	22.2	23.2	21.2	22.1	22.0	22.1
	Shrinkage in boiling water (%)	6.2	6.2	6.1	6.2	6.2	6.2	6.2	6.2
	Number of entangled after stretched (/m)	10	10	10	10	10	10	20	10

Next, the resulting synthetic fiber multifilaments were woven, scoured and thermally set to give a base fabric for non-coated air bags, also in the same manner as in Example 1. The properties of the base fabric thus obtained are in Table 4.

Table 4

		Co. Ex. 1	Co. Ex. 2	Co. Ex. 3	Co. Ex. 4	Co. Ex. 5	Co. Ex. 6	Co. Ex. 7 not scoured	Co. Ex. 8 not scoured, and not thermally set
Properties of Base Fabric	Texture density (warp/weft) (/2.54 cm)	48/48	55/55	48/48	48/48	48/48	48/48	48/48	48/48
	Cover factor (-)	1967	2255	1967	1967	1967	1967	1967	1967
	Air Permeability (cc/cm^2/sec)								
	Under low pressure (124 Pa)	0.23	0.03	0.16	0.02	0.02	0.15	0.12	0.06
	Under high pressure (19.6 KPa)	65	11	30	12	11	32	22	16
	After stretched (19.6 KPa)	96	24	72	55	59	47	57	53
	At the seams (19.6 KPa)	81	20	62	33	35	33	38	35
	Seam distortion (mm)	2.5	1.9	2.1	1.9	2.1	2.3	1.8	1.9
	Thickness of base fabric (mm)	0.29	0.37	0.28	0.27	0.27	0.28	0.27	0.27
	Tensile strength (N/cm)	623	745	614	623	616	612	613	612
	Tear strength (N)	210	250	192	193	199	192	191	189
	Number of residual entanglements (/m)	2	1	4	4	4	9	13	3
	Horizontal index (-)	-	0.94	0.87	0.96	0.95	0.72	0.84	0.93
	Residual oil content of base fabric (%)	0.04	0.06	0.04	0.04	0.03	0.05	0.20	0.15

[Comparative Example 6]

In the same manner as in Example 1, fibers for air bags and a base fabric for non-coated air bags were produced. In this, however, the fibers produced were warped under tension of 0.1 cN/dtex, and then woven. Table 3 shows the orifice profile of the spinneret used and the physical properties of the fibers produced; and Table 4 shows the properties of the base fabric produced.

[Comparative Examples 7 and 8]

In the same manner as in Example 1, fibers for air bags were produced, and these were woven into a base fabric for non-coated air bags. In Comparative Example 7, however, the woven fabric was not scoured; and in Comparative Example 8, the woven fabric was neither scoured nor thermally set. Table 3 shows the orifice profile of the spinneret used and the physical properties of the fibers produced; and Table 4 shows the properties of the base fabric produced.

As in Table 1 to Table 4, the base fabrics for non-coated air bags of the invention are all superior to the conventional base fabrics in point of the high tenacity thereof, the low air permeability thereof under low pressure, under high pressure, after stretched and at the seams, the small thickness thereof, and the compact foldability thereof to save the necessary housing space. The base fabrics for non-coated air bags of the invention

satisfy all the requirements for air bags.

INDUSTRIAL APPLICABILITY

As described hereinabove, the base fabric for non-coated air bags of the invention has the necessary properties of high tenacity, low air permeability and compact foldability to save the housing space for it, and is favorable to air bags for high-pressure inflation. The synthetic fiber multifilaments to constitute the base fabric for air bags of the invention can be readily produced in any ordinary melt-spinning process or direct spinning and drawing process, and any ordinary weaving machine can be used in weaving them into base fabrics. To that effect, the practicability of the invention is significant.